



PCT/EP 03/08942
10.09.03

10/522974
01 FEB 2005

INVESTOR IN PEOPLE

EPO - DG 1

10.09.2003

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

REC'D 18 SEP 2003

WIPO

PCT

PCT/EP 03/8942

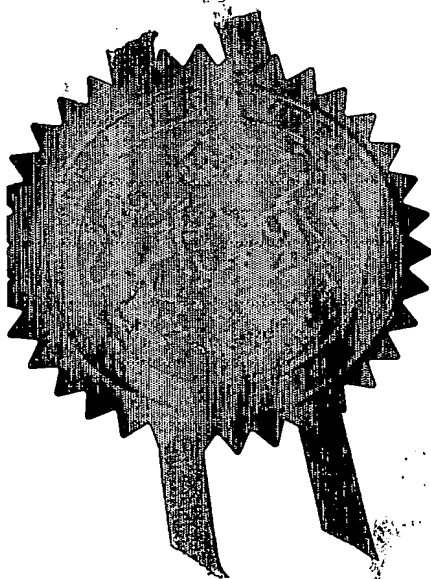
96

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.



Signed *Andrews*

Dated 14 August 2003

**PRIORITY
DOCUMENT**
SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH RULE 17.1(a) OR (b)

BEST AVAILABLE COPY

Patents Form 1/77

Patents Act 1977
(Rule 16)

The
Patent
Office

30AUG02 17:44:11.00055
P01/7750 0.000220159.8

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

THE PATENT OFFICE
A
30 AUG 2002
RECEIVED BY FAX

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference

0220159.8

AMBA198

2. Patent ap[

(The Patent Office will fill in this part)

30 AUG 2002

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Ashe Morris Limited
6 Christchurch Crescent
Radlett
Hertfordshire, WD7 8AH

8135311001

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

UNITED KINGDOM

4. Title of the invention

IMPROVED HEAT EXCHANGER

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

BAWDEN, Peter Charles

Bawden & Associates
4 The Gatehouse
2 High Street
Harpenden
Herts
AL5 2SP

Patents ADP number (if you know it)

07703572002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country

Priority application number
(if you know it)

Date of filing
(day / month / year)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number or earlier application

Date of filing
(day / month / year)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

YES

- a) any applicant named in part 3 is not an inventor, or
- b) there is an inventor who is not named as an applicant, or
- c) any named applicant is a corporate body.

See note (d))

Patents Form 1/77

Patents Form 1/77

- Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form

Description

6

Claim(s)

3

Abstract

1

Drawing(s)

6

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for preliminary examination and search (Patents Form 9/77)

Request for substantive examination (Patents Form 10/77)

Any other documents (please specify)

11.

I / We request the grant of a patent on the basis of this application.

Signature

Date

30 Aug 02

12. Name and daytime telephone number of person to contact in the United Kingdom

Peter Charles BAWDEN 01582 466700

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent of the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

- If you need help to fill in this form or have any questions, please contact the Patent Office on 0645 500505.
- Write your answers in capital letters using black ink or you may type them.
- If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.
- If you have attached 'Yes' Patents Form 7/77 will need to be filed.
- Once you have filled in the form you must remember to sign and date it.
- For details of the fee and ways to pay please contact the Patent Office.

Patents Form 1/77

0045694 30-AUG-02 12:57

PAAMBA198

IMPROVED HEAT EXCHANGER

Summary

- 5 The present invention relates to an improved method for designing and fabricating heat exchangers of the type that currently use external heating or cooling jackets, external coils or external half coils. We have found that better heat exchanger performance (in terms of temperature control and heat transfer capacity) can be achieved by using multiple small heat transfer elements rather than a single large jacket or a few large half coil elements.
- 10 Whilst some heat exchangers (such as multiple half coils and split jackets) use more than one element, the number of these elements is restricted by the cost and complexity of fabrication. Conventional wisdom dictates that heat transfer fluid turbulence should be maximised and the thickness of material between the heat transfer fluid and the process
- 15 fluid should be minimised for good heat transmission. The underlying basis of this invention is that these design criteria can be relaxed by using a greater number of much smaller pipes (carrying the heat transfer fluid) and using the full wetted perimeter of the pipes for heat transmission. To achieve this, complete pipes rather than half coils or jackets are used. By using complete pipes there is much less restriction on choice of
- 20 material (since they only need be bolted, glued, bonded or soldered rather than welded to the body of the vessel, although welding can also be used). Thus for example the heat transfer pipe can be fabricated in a material with high thermal conductivity such as copper and fixed to a glass or Hastelloy vessel. Not only does a small diameter copper pipe have a better wetted surface to volume ratio but it can transmit heat to and from the heat
- 25 transfer fluid around the full wetted perimeter. Because the pipe is small, the maximum distance between any part of the copper and the vessel surface is always relatively small. A further development of this concept is the use of pipes with a flat side to give a larger area of contact between the pipe carrying the heat transfer fluid and the wall of the process equipment. The result is a jacketed heat exchanger with multiple independent
- 30 heat transfer elements. This design not only gives better performance but it is cheaper and simpler to fabricate.

Description

- 35 The present invention relates to heat exchangers. Heat exchangers are essential for many industrial, commercial and domestic purposes. They are used to add or remove heat during processes such as exothermic or endothermic reactions, evaporation, distillation

PAAMBA198

and crystallisation etc. They are also used to modify the temperature of the materials in a wide range of industrial, commercial and domestic operations.

5 The present invention reflects the fact that better heat exchanger performance (in terms of improved temperature control and higher heat transfer capacity) can be achieved if the heat transfer surface is broken up into a large number of small elements each with an independent supply of heat transfer fluid. We have found that the use of multiple heat transfer elements permits shorter residence time of the heat transfer fluid, better distribution of the heat transfer fluid and a lower pressure drop (for a given cross sectional
10 area of the heat transfer fluid conduit) due to the shorter path length.

Building heat exchangers with multiple flow elements can be costly if conventional fabrication techniques are used. Some alternative methods can be used but incur a penalty in terms greater heat transfer resistance at the heat transfer boundary. The
15 present invention provides a low cost method of building multi element (with cross flow of the heat transfer fluid) heat exchangers that give better performance.

Many types of heat exchanger exist such as plate type, shell and tube, batch reactors etc. The types relevant to this description are heat exchangers where the following conditions
20 apply:

- (a) Heating and cooling is by an indirect method across some form of containment wall (referred to as the heat transfer wall).
- (b) The heat transfer surface is at the external boundary of the process fluid.
- 25 (c) The flow of heat transfer fluid is broken up into two or more separate elements.

Examples of heat transfer equipment that comply with (a), (b) and (c) above are shown in Figures 1 and 2.

30 A jacketed vessel will be used for this description. Two common fabrication methods for batch vessels are shown in Figures 3 and 4.

Figure 3 shows a conventional jacketed vessel. Whilst the performance of the jacket can be improved by injection nozzles or baffles, a more effective design is the half coil configuration shown in Figure 4. The half coil offers better fluid distribution and better heat
35 transfer performance. It is formed by cutting a pipe in half longitudinally and wrapping it around the body of the vessel. In this case, the half coil is shown as two separate pipes.

PAAMBA198

By using several pipes according to the present invention rather than one, the need for excessively large pipes and very high flow rates (of heat transfer fluid) can be avoided. Half coil reactors in current service usually have two or three separate elements.

- 5 The present invention therefore provides a heat exchanger in which heat transfer fluid is delivered to the heat transfer surface via multiple fully contained conduits which are separate but in intimate contact with the heat transfer surface wherein good contact between the conduit and the heat transfer surface is only required for good heat transmission and not for fluid containment.

10

The half coil jacket represents an improvement over the single jacket design. A further improvement can be made by breaking the half coil into a much larger number of small coils according to the present invention as shown in Figure 5.

- 15 In this case the coil has been reduced to a series of single hoops resulting in much shorter flow paths. This design offers faster replacement of heat transfer fluid which is desirable for good temperature control. The average temperature difference (between the heat transfer fluid and the process fluid) can also be higher than that of the half coil design since the fluid is only making a single turn rather than many turns. The individual coils preferably have cross sectional flow areas of 500mm² or less, preferably 200mm² or less, more preferably 100mm² or less, more preferably 20mm² or less and sometimes 1mm² or less.

- 25 Whilst the multiple hoop solution has advantages, the half coil design is relatively costly to fabricate. An illustration of the conventional half coil fabrication method is shown in Figure 6.

- 30 A conventional half coil jacket is made from a pipe cut in half longitudinally and wrapped around the heat transfer surface. The half coil is then welded to the heat transfer surface along its full length to form a continuous contained flow channel for the heat transfer fluid. At the start and end of the half coil, a transition from half coil to full pipe has to be made to connect it to the supply and return pipes. This is a relatively complex and time-consuming method of fabrication. A further implication of using multiple feed and take off points (of heat transfer fluid) has to be considered. As the number of feed and take off points increases, the pipe diameter gets smaller (unless very high flow rates of heat transfer fluid are to be used) and a much large number of smaller pipes are needed to cover the surface area. This increases the fabrication cost substantially.

PAAMBA198

An alternative design method is to use a complete pipe as shown in Figure 7.

In Figure 7, fabrication of the inlet and take off points are simplified since these are a continuation of the pipe. The need to cut the pipe longitudinally is also eliminated. An additional and major advantage is that a substantially different material can be used for the heat transfer pipe. This arises because no welding is required to maintain containment integrity of the heat transfer fluid. Thus the heat transfer pipe (or conduit) can be joined to the heat transfer surface by bolting, screwing, soldering, braising or gluing to the heat transfer surface (it should be noted that bolting and screwing are less desirable since they do not necessarily eliminate the air gap between the pipe and the heat transfer surface). This permits the use of materials with better thermal conductivity (such as copper or aluminium). A disadvantage with this method is that the geometric profile of a round pipe section increases the distance between the heat transfer fluid and the process fluid. This increases the thermal resistance. This is compensated for to some extent by the fact that smaller heat transfer pipes are used. In this case the bonding material for the pipe to the body of the vessel should have good thermal conductivity properties.

A further improvement to the full pipe solution is to use a pipe (or conduit) that has a flat side in contact with the heat transfer surface as shown in Figure 8.

As Figure 8 shows, the pipe cross section can be square, rectangular, D shape, triangular or any other shape providing a flat face is in contact with the heat transfer surface. Today there are methods of fabricating copper pipes (and other materials) with unusual profiles. It is also possible to fabricate pipes of this shape and retain the round ends. By retaining the round ends, joining of the end connections to the manifold is simplified.

Because the pipe is complete (and not cut through longitudinally), no welding is required. It is important however to eliminate air gaps between the pipe (carrying the heat transfer fluid) and the heat transfer surface. For this reason, the pipe is preferably fixed to the heat transfer wall by a continuous layer of material with good thermal conductivity. Suitable materials include: solder, silver solder, braising, thermally conductive cements or any other bonding material with good thermally conductive properties.

Although soft materials such as copper have less strength, this is compensated for by the fact that smaller diameter pipes have inherently higher design pressures. The pipes have smaller diameters by virtue of the fact that a much greater number of them are used.

PAAMBA198

The heat transfer characteristics of the flat-sided full coil of the invention are different to the conventional half coil as illustrated in Figure 9 which shows the heat transfer mechanism of a half coil compared to a modified full coil design.

5

In the case of the half coil, the cross sectional area of flow is relatively large (typically $>500 \text{ mm}^2$) and the flow conditions are generally turbulent. Turbulent flow is desirable for good heat transmission between the heat transfer fluid and the heat transfer surface. The absence of a pipe wall on the process side of the half coil is also desirable since this reduces the distance that heat has to flow between the heat transfer fluid and the process fluid. The half pipe wall is fabricated in a material which can be welded to the heat transfer wall. This is usually steel or stainless steel. Whilst some heat will be transmitted via the walls of the pipe, this is a relatively small proportion of overall heat transferred.

10

15

In the case of the modified full coil shown in Figure 9, the cross sectional area is small (usually $<500 \text{ mm}^2$ and more generally $<100 \text{ mm}^2$) and the flow conditions will often be laminar. The full coil method also has an additional layer of material between the process fluid and the heat transfer wall. On the face of it, the laminar flow conditions and additional wall thickness might suggest inferior heat transfer properties. In practice the opposite is true. Although laminar flow is not ideal for good heat transfer, pipes used in the multi pipe solution have much smaller diameters. The small diameter offers a larger wall surface area per unit volume of heat transfer fluid. Given that very thermally conductive pipes can be used (the thermal conductivity of copper for example is more than 20 times higher than that of stainless steel), the full wetted circumference of the heat transfer pipe can be exploited for heat transmission as shown by the arrows in the diagram above. A variety of internal shapes can also be used to increase the surface to volume relationship. If necessary more elaborate shapes can be used to exploit the high thermal conductivity of materials like copper. Some examples are shown in Figure 10.

20

25

30

A further improvement in performance can be achieved by inserting baffles and flow disrupters within the pipes.

A jacketed vessel or jacketed pipe fabricated with numerous small conductor pipes has different appearance to conventional jacketed heat exchangers as shown in Figure 11.

35

The design as shown in Figure 11 has many advantages:

PAAMBA198

- The conductor pipes are simple to fix to the vessel by bolting, screwing, soldering, braising or gluing. (Note that bolting and screwing are not ideal in some cases as these methods may leave an air gap)
- 5 • The conductor pipes are also simple to connect to the manifold since they can be fabricated with circular end profiles thus they can be connected with soldering, braising or compression fittings.
- The conductor pipes give improved heat transfer capacity and faster fluid replacement speeds.
- The small diameters of the conductor pipes make them comparatively strong.
- 10 • The conductor pipes can be repaired and replaced in situ.
- The design can be used with any vessel material such as glass, glass lined steel, stainless steel, carbon steel, Hastelloy etc.

15 This design not only delivers better performance for jacketed vessels and pipes, but will be simpler and cheaper to build. The number and size of the conductor pipes will depend upon the size of the vessel whose temperature is to be controlled and the nature of the medium whose temperature is to be controlled. However as many as several hundred pipes could be employed on a large vessel.

20 Typically the invention employs from 5 to 100 conduits. Preferably 5 or more, more preferably 10 or more, most preferably 50 or more. In the case of large vessels 100 or more conduits for example up to 250 conduits may be used.

PAAMBA198

CLAIMS

1. A heat exchanger in which heat transfer fluid is delivered to the heat transfer surface via multiple fully contained conduits which are separate but in intimate contact with the heat transfer surface wherein good contact between the conduit and the heat transfer surface is only required for good heat transmission and not for fluid containment.

2. A heat exchanger according to Claim 1 where the heat transfer fluid conduit has at least one side flattened in cross sectional view and this side is held in intimate contact with or joined to the heat transfer surface.

3. A heat exchanger according to either of Claims 1 or 2 where the heat transfer conduit is made from a single piece of material or two pieces of material joined in the longitudinal axis and the cross sectional profile of the flow path of the conduit is modified to different shapes so as to improve the ratio of wetted area of the conduit to conduit volume.

4. A heat exchanger according to any of the Claims 1 to 3 where 5 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

5. A heat exchanger according to any of the Claims 1 to 3 where 10 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

6. A heat exchanger according to any of the Claims 1 to 3 where 50 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

7. A heat exchanger according to any of the Claims 1 to 3 where 100 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

8. A heat exchanger according to any of the preceding Claims where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 500 mm² or less.

9. A heat exchanger according to any of the Claims 1 to 7 where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 100 mm² or less.

PAAMBA198

- 5
10. A heat exchanger according to any of the Claims 1 to 7 where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 20 mm² or less.
11. A heat exchanger according to any of the Claims 1 to 7 where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 1 mm² or less.
- 10 12. A heat exchanger according to any of the preceding Claims where the conduits used to deliver the heat transfer fluid to the heat transfer surface are made of material having a thermal conductivity of greater than 100 W/m.k.
- 15 13. A heat exchanger according to any of the Claims 1 to 12 where the conduits used to deliver the heat transfer fluid to the heat transfer surface are made of material having a thermal conductivity of greater than 10 W/m.k.
14. A heat exchanger according to any of the Claims 1 to 13 where the conduits used to deliver the heat transfer fluid are made of copper or copper alloy.
- 20 15. A heat exchanger according to any of the preceding Claims which controls the process temperature by varying the heat transfer area.
16. A heat exchanger according to any of the preceding Claims which delivers heat transfer fluid by cross flow.
- 25 17. A heat exchanger according to any of Claims 1 to 16 that is a batch reactor.
18. A heat exchanger according to any of Claims 1 to 16 that is a continuous reactor.
- 30 19. A heat exchanger according to any of Claims 1 to 16 that is used for heat transfer in nuclear reactions.
20. A heat exchanger according to any of Claims 1 to 18 that is a crystalliser.
- 35 21. A heat exchanger according to any of Claims 1 to 18 that is used for fermentation or growth of plant or animal cells.

PAAMBA198

22. A heat exchanger according to any of Claims 1 to 18 that is used for evaporation or drying

5 23. A heat exchanger according to any of Claims 1 to 18 that is used for distillation.

24. A heat exchanger according to Claims 1 to 18 that is used to heat or cool supercritical fluids.

10 25. A heat exchanger according to Claim 24 that is used to heat or cool supercritical fluids during expansion.

26. A heat exchanger according to any of Claims 1 to 25 that is used in food manufacturing processes.

15

27. A heat exchanger according to any of Claims 1 to 25 that is used for manufacturing pharmaceutical compounds.

20 28. A heat exchanger according to any of Claims 1 to 25 that is used for chemical manufacturing processes.

PAAMBA198

ABSTRACT

A heat exchanger in which heat transfer fluid is delivered to a heat transfer surface via multiple fully contained conduits which are separate but in intimate contact with the heat transfer surface. Good contact between the conduit and the heat transfer surface is only
5 required for good heat transmission and not for fluid containment. Typically 5 or more conduits are used to deliver heat transfer fluid to the heat transfer surface and the conduits have cross sectional flow areas of 500 mm² or less.

PAAMBA198

SHEET 1 OF 6

Figure 1.
Batch vessel

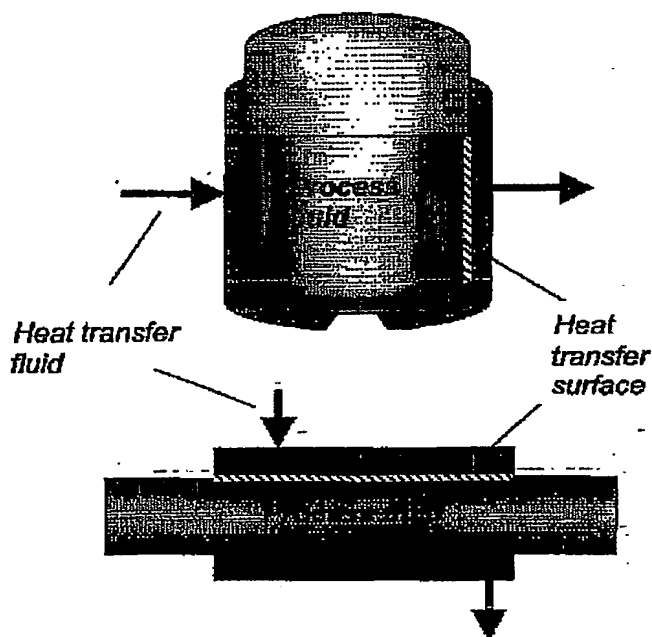


Figure 2.
Jacketed pipe

PAAMBA198

SHEET 2 OF 6

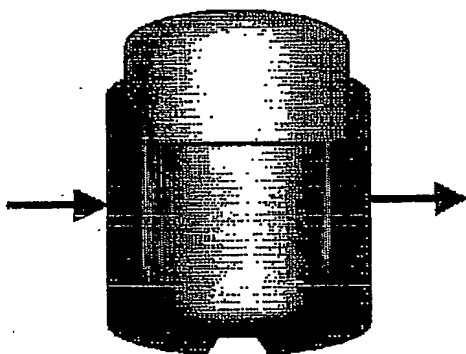


Figure 3.
Conventional jacket

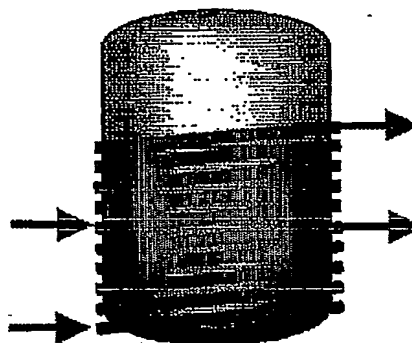


Figure 4.
Half coil jacket
(with two feed and two
discharge points for the heat
transfer fluid).

PAAMBA198

SHEET 3 OF 6

Figure 5.
Half coil jacket with multiple take offs.
(This could also be described as a type of cross flow (of the heat transfer fluid) heat exchanger.

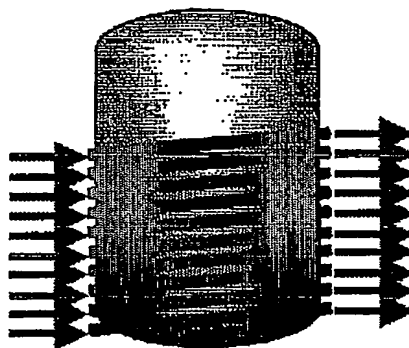
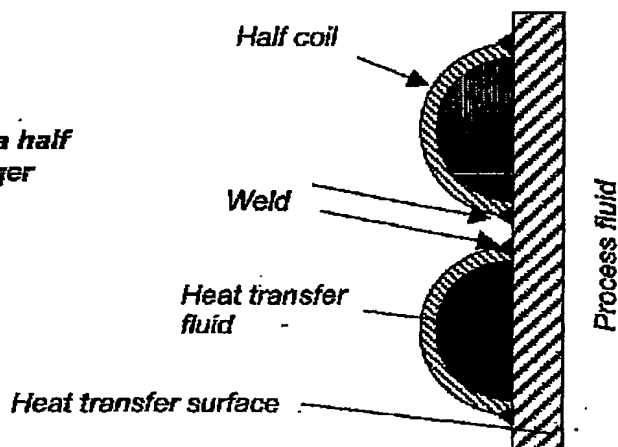


Figure 6.
Section through a half coil heat exchanger



PAAMBA198

SHEET 4 OF 6

Figure 7.
 Heat transfer fluid pipe
 welded to heat transfer
 surface.

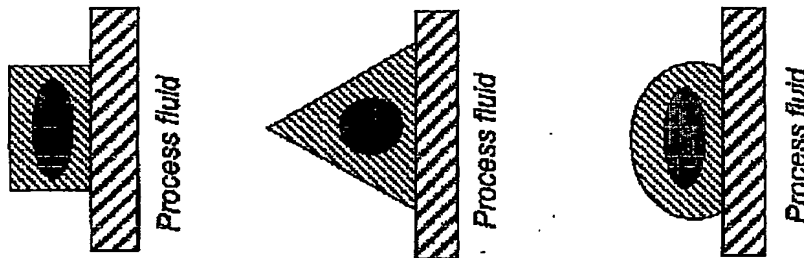
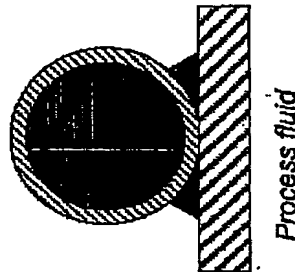
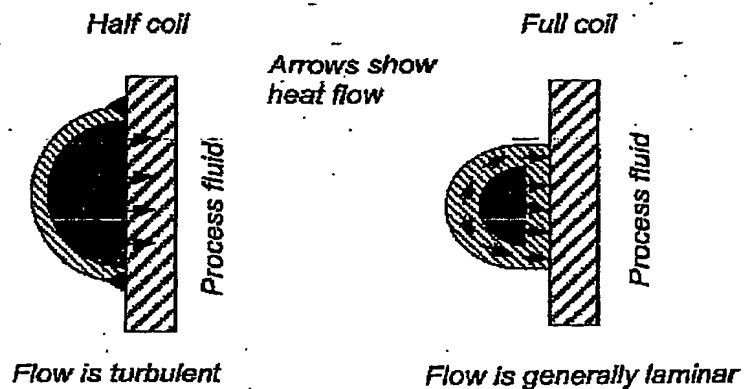


Figure 8 Some Alternative shapes for flat-sided heat transfer fluid pipe

Figure 9.
 Heat flow in half
 coil and flattened
 full coil.



PAAMBA198

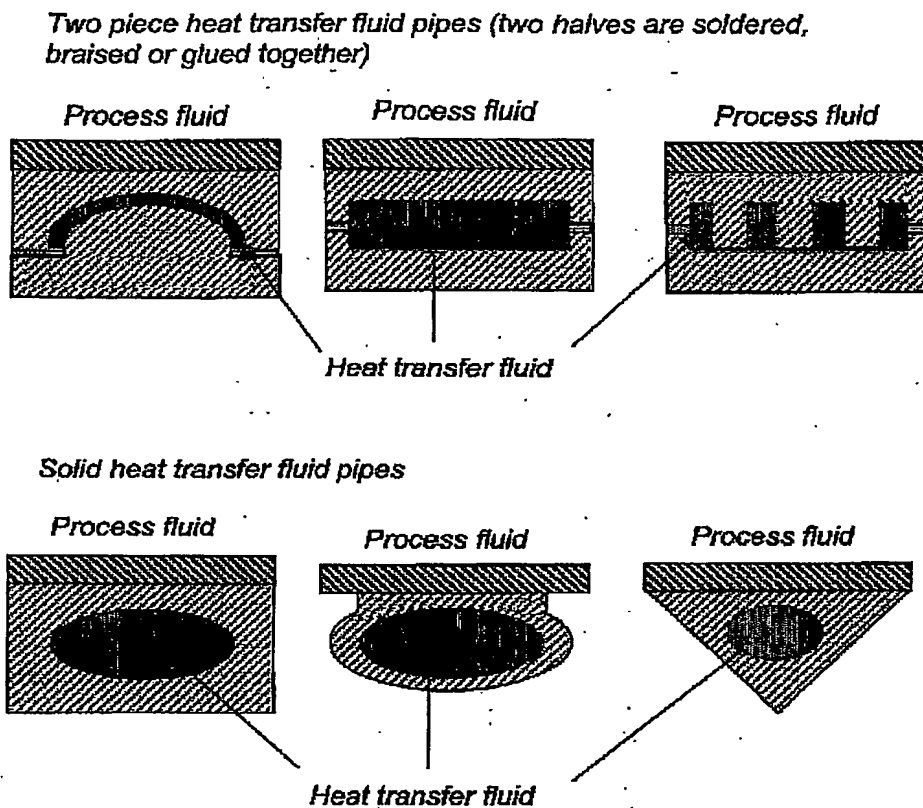


Figure 10.
Examples of heat transfer conduits with different internal and external profiles as shown in cross section.

PAAMBA198

SHEET 6 OF 6

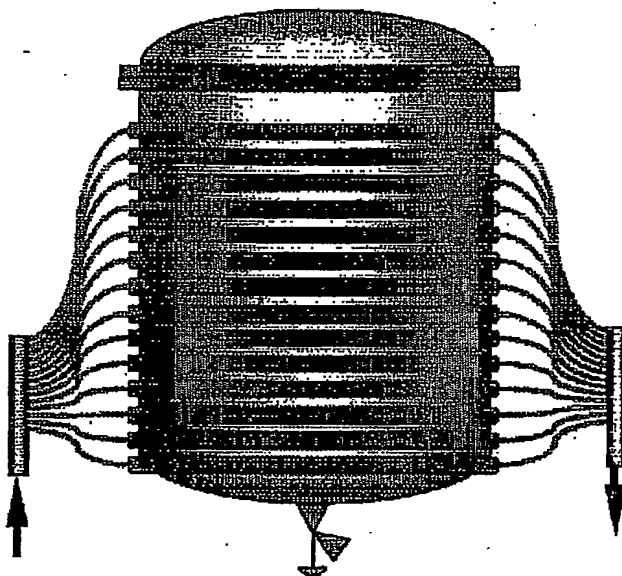


Figure 11.
***Multi tube jacketed vessel using copper conductor pipes (the
conductor pipes may number several hundred on a large vessel).***

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☒ **FADED TEXT OR DRAWING**
- ☒ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☒ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☒ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.